Heat Transfer Enhancement and Thermal Management for Space Applications Employing Femtosecond Laser Processed Metallic Surfaces with Micro/Nanostructures

Completed Technology Project (2014 - 2018)

Project Introduction

Thermal management is one of the most important challenges in space applications. The success of space exploration and travel is directly tied to how we efficiently convert, transfer, and store energy in energy systems such as maintaining cryogenic fluids for propulsion, protection of vehicles from aerodynamic heating, and maintaining comfortable living conditions for crew. This energy transfer takes the form of heat acquisition, heat transport, and heat rejection. An effective thermal control system must provide these three basic functions while being mindful of the operational environment and spacecraft system. At the heart of this energy conversion is interfacial heat transfer especially that between solids and liquids/gases, which can be significantly enhanced using nanotechnology-enabled functionalized surfaces. Functionalized surfaces with tailored thermal and wettability properties can be fabricated using Femtosecond Laser Surface Processing (FLSP); engineered surface properties are obtained by the production of self-organized microstructures covered by layers of nanoparticles. Preliminary results using such surfaces have displayed very promising heat transfer properties with extraordinary shifts of the Leidenfrost temperature and enhancement of both the pool boiling heat transfer coefficients and critical heat flux. The observed extraordinary heat transfer is attributed to both the microstructure and the presence of self-assembled nanoparticles on top of the microstructures, through the collective contributions of effective thermal conductivity, high liquid wetting and capillary wicking, high nucleation site density, and the formation of nanobubbles from three-dimensional nanocavities. Understanding the fundamental causes of augmented heat transfer in FSLP fabricated multiscale metallic micro/nano structured surfaces is expected to foster breakthrough applications in energy conversion and storage. Knowledge acquired from the proposed research can be used in the design of more compact and efficient heat exchangers and cold plates used in space applications, thus dramatically reducing the hardware mass and volume. In addition, the FSLP technique does not use any coatings or thin film depositions as the microstructures and nanoparticles are created from the base metallic material. This technique can therefore have significant advantages in permanency over organic coatings in high temperature conditions found in space applications. The research objective of this proposal is to experimentally investigate the interfacial two-phase transfer mechanisms of pool boiling and flow boiling heat transfer on FSLP multiscale functionalized nano/microstructured surfaces.

Anticipated Benefits

Understanding the fundamental causes of augmented heat transfer in FSLP fabricated multiscale metallic micro/nano structured surfaces is expected to foster breakthrough applications in energy conversion and storage. Knowledge acquired from the proposed research can be used in the design of more

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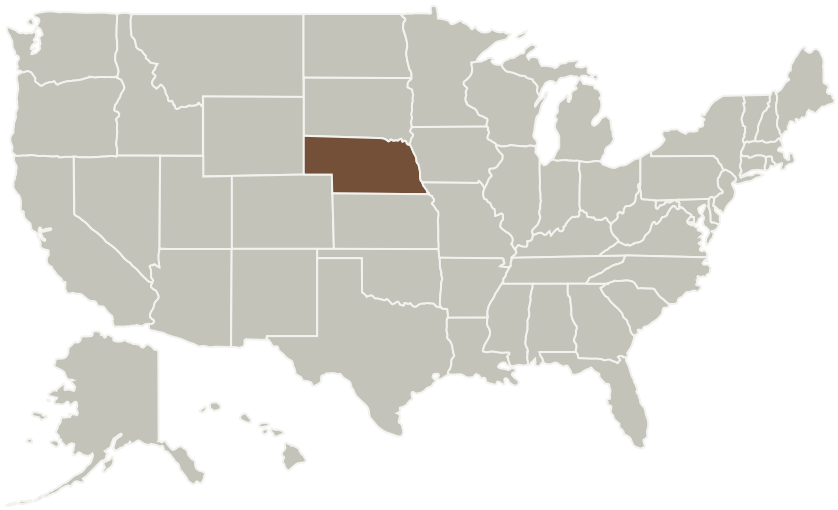
Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Nebraska

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

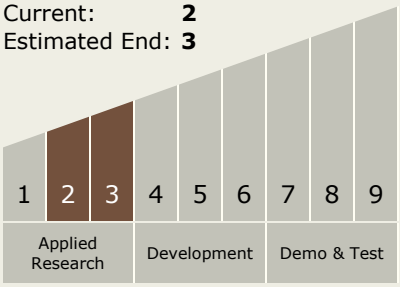
Sidy Ndao

Co-Investigator:

Corey M Kruse

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



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Technology Areas

Primary:

- TX14 Thermal Management Systems
  - TX14.2 Thermal Control Components and Systems
    - TX14.2.1 Heat Acquisition

Target Destinations

The Moon, Mars, Others Inside the Solar System